Selected topics in Computer Vision

CS3243 Foundations of Artificial Intelligence

(Textbook section 24.2, 24.3, 24.5, 24.6)
Slides due to Huang Weihua
Outline

- Image formation
- Low-level Vision
  - Smoothing
  - Edge detection
- High-level Vision
  - Object recognition
    - Brightness-based approach
    - Feature-based approach
- Application of Computer Vision
  - Manipulation
  - Navigation
In computer vision, an image is a two-dimensional grid of pixels.
Image Formation

- Perspective projection: a process of projecting an object in a scene on an image plane.

\[-\frac{x}{f} = \frac{X}{Z}, \ -\frac{y}{f} = \frac{Y}{Z}\]
\[x = -\frac{fX}{Z}, \ y = -\frac{fY}{Z}\]
Visible light comes in a range of wavelengths: 400 nm (the violet end) to 700 nm (the red end).

Discrete representation:
- Black and white (1 bit)
- Grayscale: 0-255 brightness (1 byte)
- RGB combination: each from 0-255 (3 bytes)
Image Formation
Low-level Vision

- **Smoothing**: removing extreme values from the image.
- **Gaussian filter**: replacing the original pixel $I(x_0, y_0)$ by summation of $I(x, y)G_\sigma(d)$ over all pixels, where:

  \[ G(x) = \frac{1}{\sqrt{2\pi\sigma}}e^{-\frac{x^2}{2\sigma^2}}, \text{ in one dimension.} \]

  \[ G(x, y) = \frac{1}{2\pi\sigma^2}e^{-\frac{x^2+y^2}{2\sigma^2}}, \text{ in two dimensions.} \]

  And $d$ is the distance between pixel $(x, y)$ and $(x_0, y_0)$

- **Convolution**: $h = f \ast g$ (Weighted sum)
Low-level Vision

Original Image

$\sigma = 2.0$

$\sigma = 4.0$
Low-level Vision

- **Edge detection**: finding lines and curves in the image plane that have significant change in brightness.

- Theorem: \((f * g)' = f * g'\)

- **Canny edge detection**: combining the Gaussian smoothing process and edge detection process.
Low-level Vision

Original Image

Edges extracted
Low-level Vision

After edge detection, we can segment the edges into visual groups that are single objects or parts of an object.

Segmentation is based on similarities of certain visual properties, such as:

- Brightness
- Color
- Texture
- Gradient
High-level Vision

Object recognition

- Applications: Biometric identification, content-based image retrieval, handwriting recognition, etc.

High-level Vision

- **Brightness-based** recognition

  - Basic feature: the brightness of pixels.

  - Statistical approach to detect certain objects, such as faces and cars.

  - Disadvantage: great redundancy inherent in the representation.
High-level Vision
High-level Vision

- **Feature-based recognition**
  - Basic feature: regions and edges
  - Classification approach: finding configuration of edges corresponding to views of object.
  - Deformable matching: using simple coordinate transformations.
  - Shape context: arrangement of shapes.
High-level Vision

(a) Sample point 1

(b) Sample point 2

(c) Log-polar histogram

(d) Sample point 1

(e) Sample point 2

(f) Sample point 3

(g)
Application of Computer Vision

- **Manipulation**
  - Direct processing on the objects.
  - Example: manipulating engineering drawings.

- **Navigation**
  - Moving without colliding with obstacles.
  - Example: navigation system for an auto-driving vehicle.
Application of Computer Vision
For more information

You can learn more from the following modules:

- CS3241 Computer Graphics.
- CS4243 Computer Vision and Pattern Recognition.

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